(12) UK Patent Application (19) GB (11) 2 276 288 (13) A

(43) Date of A Publication 21.09.1994

(21) Application No 9305343.7

(22) Date of Filing 16.03.1993

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(51) INT CL[5]
H03F 3/19 1/08

(52) UK CL (Edition M)
H3W WUV
H3T T2L T2T3B T2T3F

(56) Documents Cited
US 5177452 A

(58) Field of Search
UK CL (Edition L) **H1W WFA WFX WGA WGP, H3W WUV WVT**
INT CL[5] **H01P 5/02, H03F 1/08 1/56 3/19 3/191 3/193**
ONLINE DATABASES: WPI, INSPEC

(54) Stabilisation circuit for microwave amplifiers and active networks using butterfly stub

(57) The invention describes a microwave stabilisation network which demonstrates a solution to instability and conditional stability problems associated with high frequency solid state devices for microwave circuits. The circuit can be constructed as a stand alone stabilisation network or can be arranged to form part of a dc biasing network. It comprises a transmission line of around a quarter wavelength leading to a butterfly stub. The arrangement includes a set of stabilisation resistors configured to ensure stability across the entire frequency spectrum.

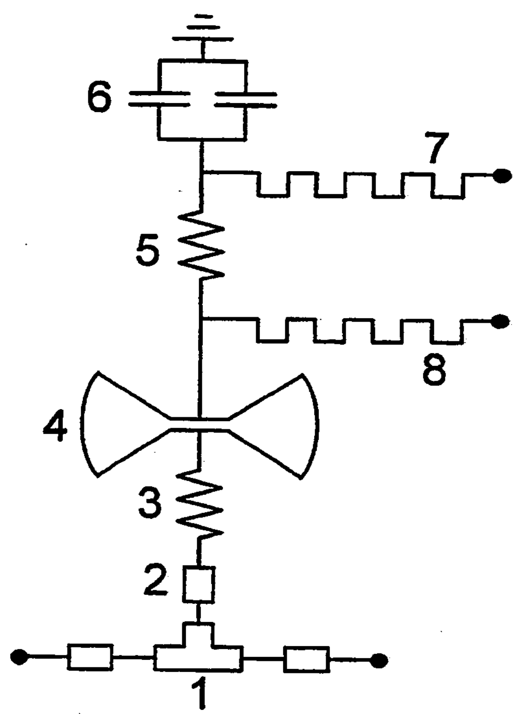

FIGURE 1
NOVEL STABILISATION CIRCUIT FOR MICROWAVE AMPLIFIERS AND ACTIVE CIRCUITS

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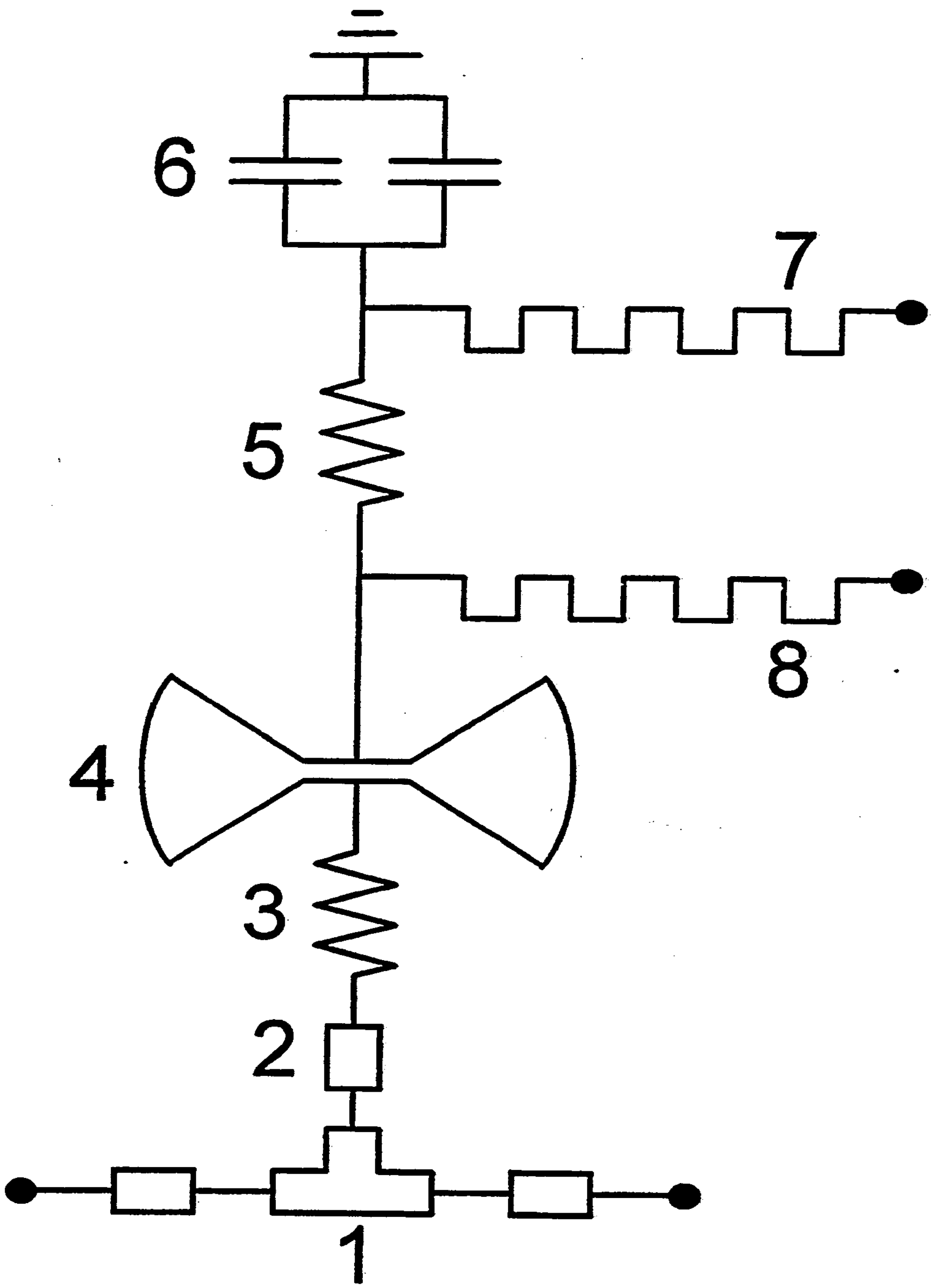


FIGURE 1
NOVEL STABILISATION CIRCUIT FOR MICROWAVE AMPLIFIERS AND ACTIVE CIRCUITS

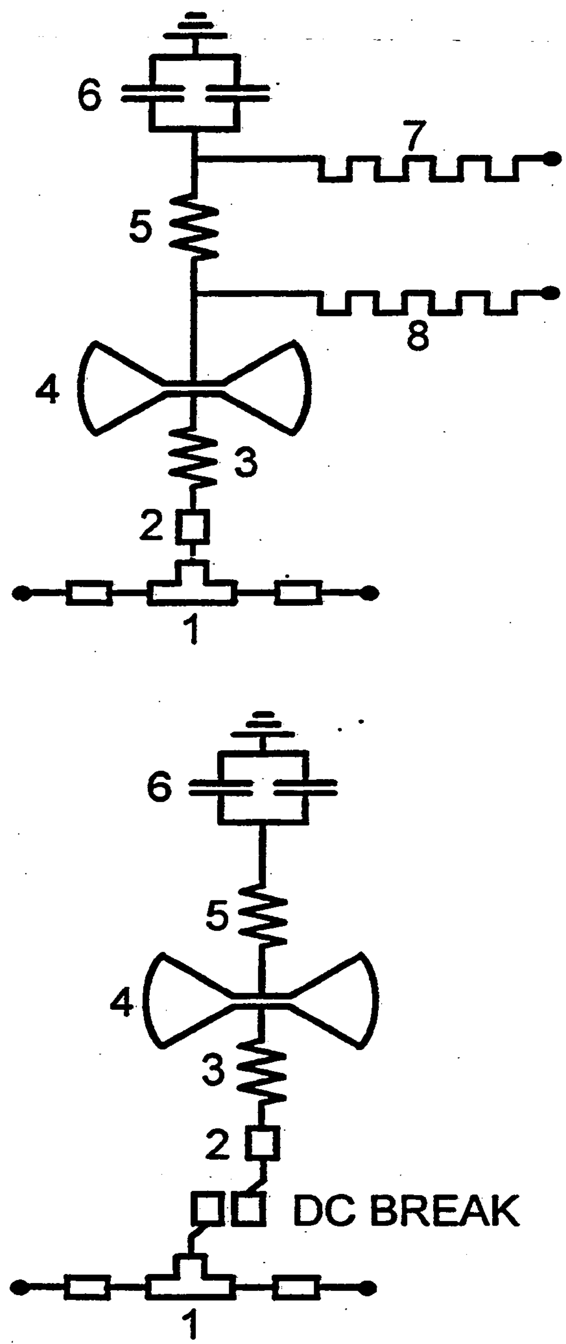


FIGURE 2
DIFFERENT CIRCUIT CONFIGURATIONS OF THE DESCRIBED STABILISATION CIRCUIT

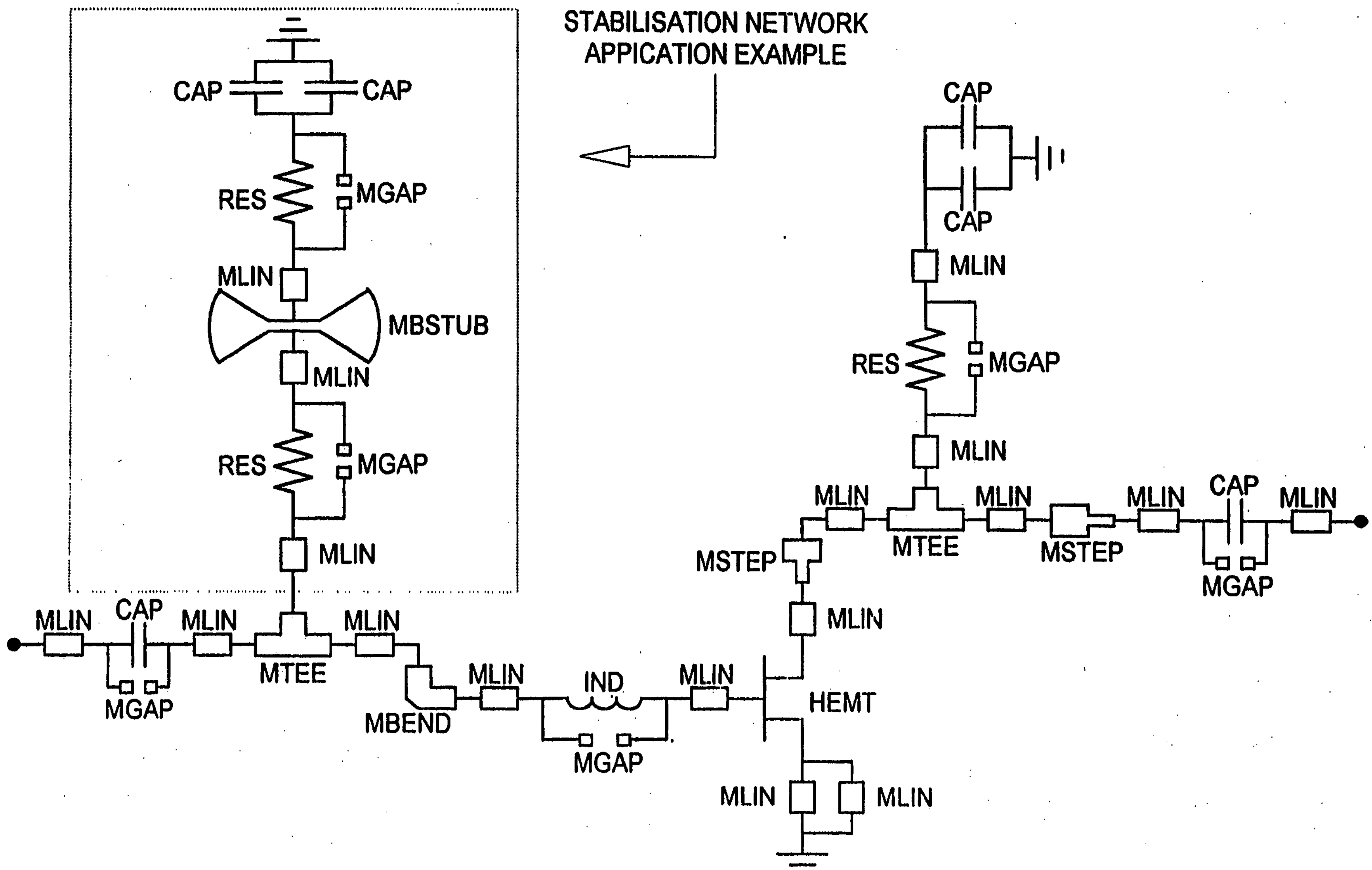


FIGURE 3a-STABILISATION CIRCUIT APPLICATION EXAMPLE
(a- SCHEMATIC CIRCUIT)

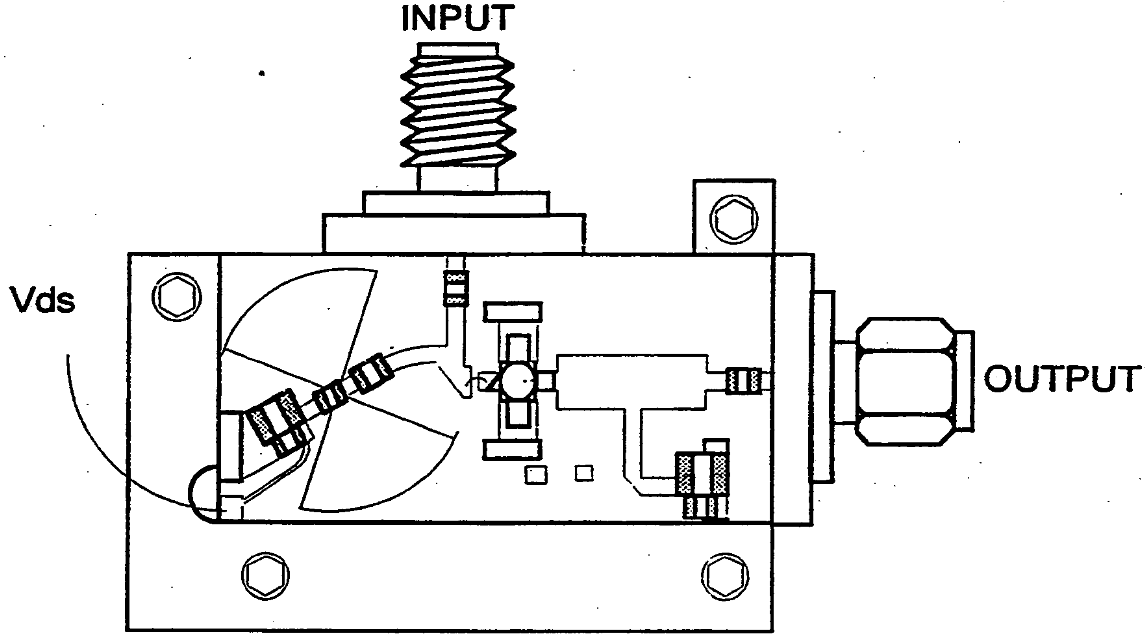
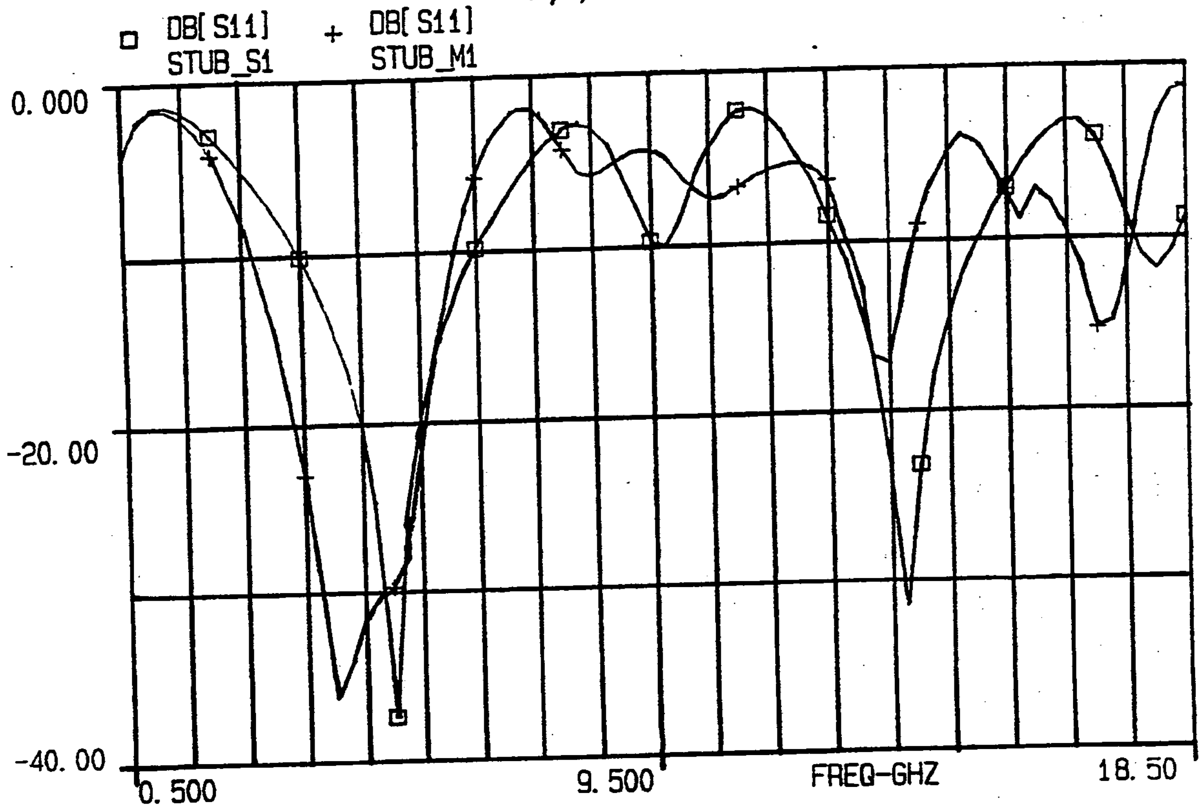


FIGURE 3b-STABILISATION CIRCUIT APPLICATION EXAMPLE
b- C-BAND LNA ASSEMBLY



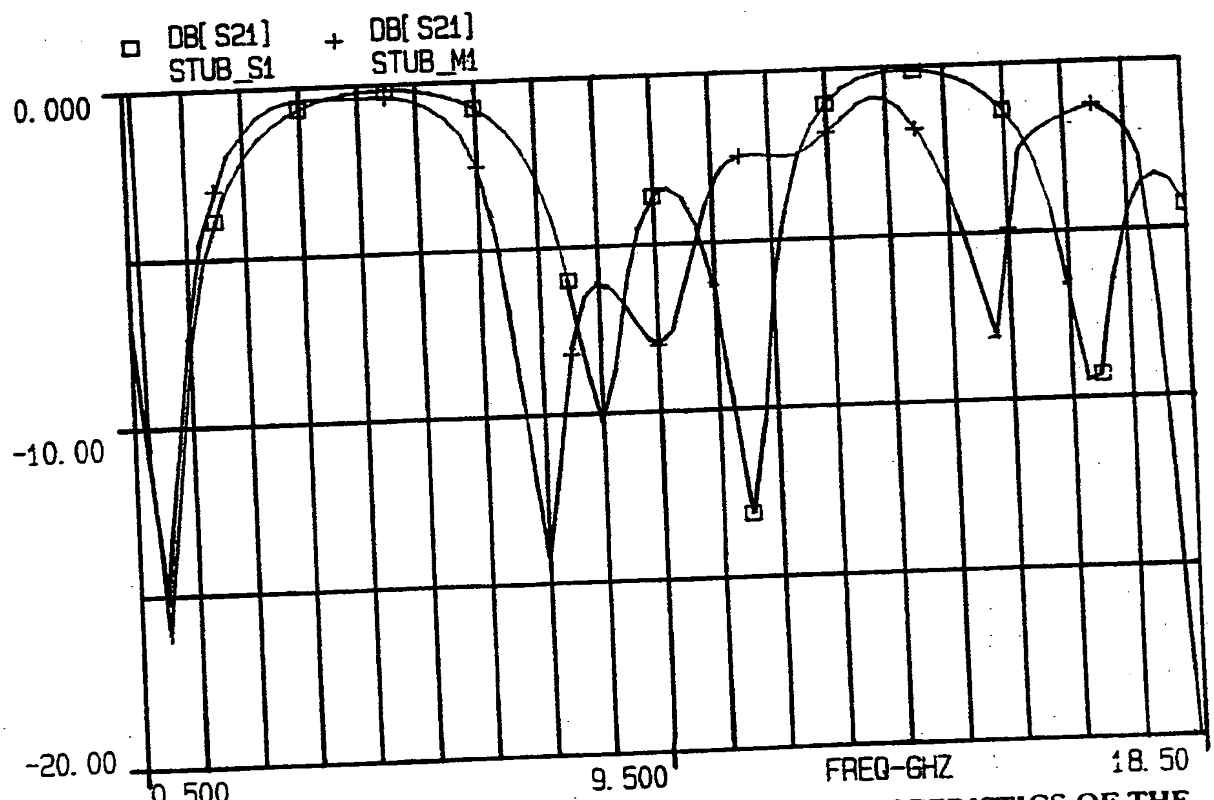


FIGURE 4 : MEASURED AND SIMULATED CHARACTERISTICS OF THE STABILISATION NETWORK

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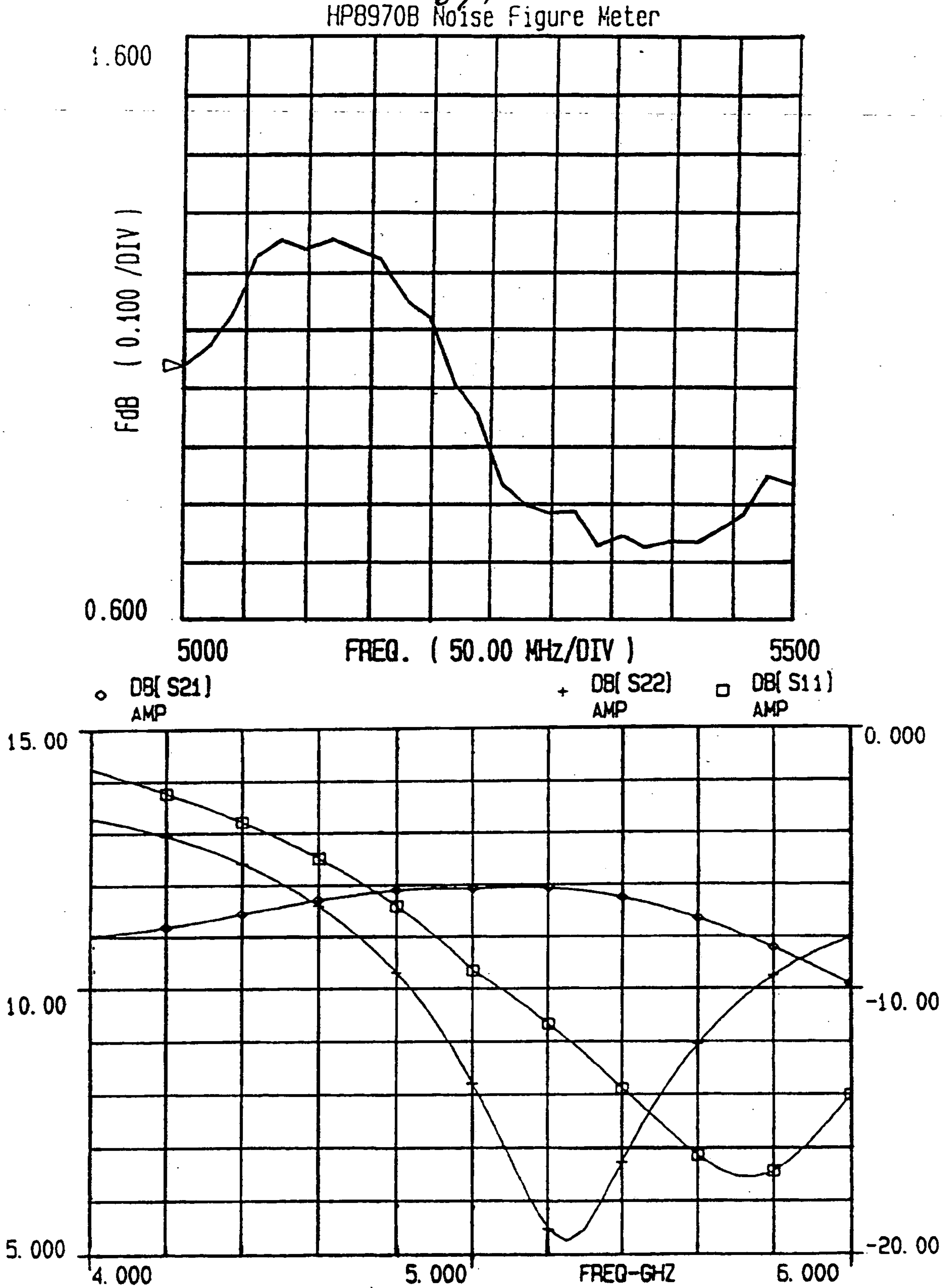

FIGURE 5a - 5b: C-BAND LNA CHARACTERISTICS
a - NOISE FIGURE
b - GAIN AND VSWR

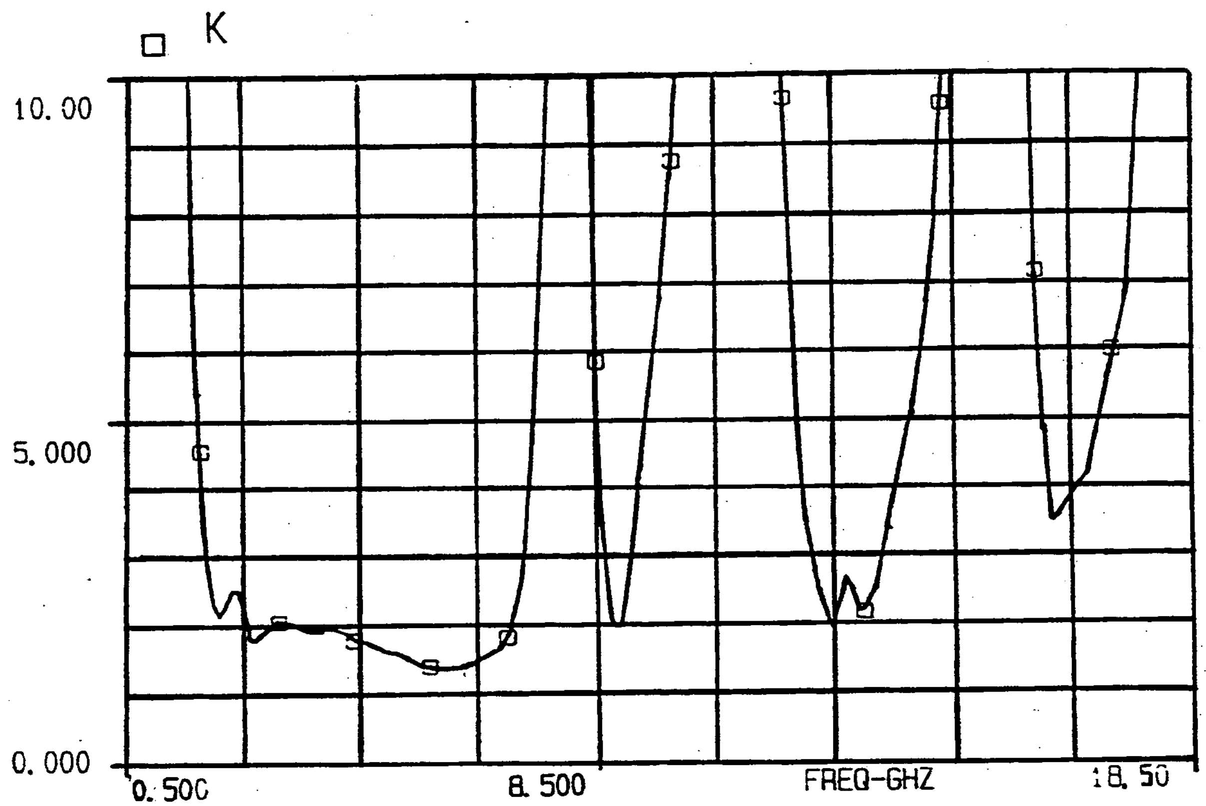

FIGURE 5c: C-BAND LNA CHARACTERISTICS
c - STABILITY FACTOR K

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STABILISATION CIRCUIT FOR
MICROWAVE AMPLIFIERS AND NETWORKS

<u>CONTENTS</u>

ABBREVIATIONS

dc	:	direct current
rf	:	radio frequency
HEMT	:	High Electron Mobility Transistor
HBT	:	Heterojunction Bipolar Transistor
MESFET	:	Metal Semiconductor Field Effective Transistor
LNA	:	Low Noise Amplifier
SSPA	:	Solid State Power Amplifier

2.0 BACKGROUND OF THE INVENTION

Solid state microwave amplifiers are widely used in most communication networks. The components used to realise these networks are largely based on two-port solid state microwave components which could have drastic affects on equipment performance if a failure such as instability occurs. It is of extreme importance to avoid any instability behaviour, as the effects of it would result in equipment failure and could result in destruction or degradation of other functional equipment.

The conventional solution to the problem has been to design impedance matching networks which ensure unconditional stability at and around the operation bandwidth and to use $n\lambda g/4$ long bias lines with short circuit reference points, where n is an odd integer number. In addition to these, where instability is restricted to narrow bands, shunt resonance circuits are used. The commonly used features of the $n\lambda g/4$ bias lines include stabilisation resistors and rf decoupling capacitors. The non-ideal characteristics of the circuit elements and narrow band characteristics of $\lambda g/4$ often leads to in-band performance degradation. These commonly used design techniques will often only yield conditional stability. Where high frequency devices such as HEMTs, HBTs and small gate periphery, high frequency MESFETs are used at lower bands, such as L- and C-bands, the achievement of good stability margins or unconditional stability conditions is much more difficult. The problem is often solved using two separate networks; the rf matching network which defines the in-band characteristics and the stabilisation network which can be designed to effect out-of-band characteristics. The invention presented describes a stabilisation circuit which provides an effective tool for ensuring unconditional stability, shaping the out-of-band characteristics without degrading in-band performance.

3.0 **DESCRIPTION OF THE INVENTION**

The circuit performs the function of stabilisation by effecting the out-of-band characteristics of a network in a predetermined manner. The performance can be optimised using CAD techniques. The circuit provides a design tool which can be built in microwave and higher frequency circuits to achieve unconditional stability characteristics.

3.1 **Qualitative Description of the Circuit Function**

The schematic diagram of the circuit is shown in Figure 1. The construction is based on the open circuit characteristics defined by the butterfly-stub, element number (4), which connects to the main transmission line via the resistor labelled number (3) and a bias transmission line, labelled number (2). The butterfly-stub serves the prime function of defining a virtual open circuit over 5% bandwidth about a centre frequency f_o. The total electrical length from the T-junction to the open circuit reference point of the butterfly-stub, l_T is half a wavelength at f_0, i.e. 180°.

$$l_T = l_{e1} + l_{e2} + \delta l = 180°$$

where:

l_{e1} is the effective electrical length of the butterfly-stub

l_{e2} is the effective electrical length of the transmission line labelled (2) in figure 1.

δl is the added electrical length of the stabilisation resistor labelled (3).

An important feature of the network concerns the two stabilisation resistors (3) and (5), used on either side of the butterfly-stub. As a result of this arrangement any in-band signal sees more of (3) and virtually none of (5), and any out-of-band signal over selected frequency bands sees both of the resistors and is hence significantly attenuated which reduces the magnitudes of S21 and S12. The elements labelled (2), (3), (4) and (5) can be carefully chosen to attenuate selected out-of-band frequencies with very little or no in-band insertion loss increase. Depending on circuit performance requirements, a small degradation of in-band insertion loss can be traded-

off for improved stability performance. The circuit offers a versatile stabilisation network with two separate stabilisation resistors; one for in-band effects and the other for out-of-band effects. Where the in-band stability is very good and further improvement is not needed, the first resistor (element number (3)) can be shorted. These features are of extreme importance in LNA and SSPA designs. In the case of the former the input circuit is mismatched to optimise NF performance. This often results in a need for a small improvement in the K-factor across the operation band and a substantial improvement in the out-of-band K-factor. Where high gain, high frequency, low noise devices are used, the instability problem becomes more difficult to solve and the described design network could provide the ultimate solution. The preferred dc bias line in LNA applications would be via a high impedance line, labelled (7). In the latter case, i.e. in SSPAs, it is more suitable to integrate this circuit to its output network, and to apply dc bias via the high impedance line, labelled (8). Where efficiency of the unit is very critical the bias point can be arranged to connect at the junction between the butterfly-stub, element (5) and the low value stabilisation resistor, element (3).

3.2 Theoretical Description

The theory of unconditional stability is defined by Rollett Stability Factor, K [1]

$$K = \frac{1 + |D|^2 - |S11|^2 - |S22|^2}{2\,|S12.S21|}$$

The condition for unconditional stability is:-

$$K > 1$$

$$S11 < 1$$

$$S22 < 1$$

where Sij defines scattering parameters of a two port network,

$i = 1, 2$ and $j = 1, 2$

$$D = S11.\,S22 - S12.S21$$

4.0 TECHNICAL RESULTS

To assess the effectiveness of the presented circuit a C-band LNA was designed and built. The described effects of the stabilisation network were analysed using CAD techniques and the practical performance was tested. Computer analysis of the modelled network was observed to be in good agreement with the measured data.

4.1 Application Notes

The presented invention has a wide range of applications in various microwave and higher frequency active networks. The prime application area encompasses different amplifier types ranging from LNAs to SSPAs. Some of the other applications may extend into transistor based switching networks. Different configuration of the circuit are shown in Figure 2. The dc block shown in Figure 2a can be used in fast switching networks to eliminate or alleviate time constraints introduced by decoupling capacitors. An application example of the circuit used in a LNA stage is shown in Figure 3.

4.2 Typical Measured Performance

VSWR and insertion loss characteristics of the stabilisation circuit is shown in Figure 4. The simulated and measured characteristics of the LNA are shown in figure 5 which demonstrates the effectiveness of the stabilisation network in circuit applications.

[1] S.Y. Lioa, "*Microwave Circuit Analysis and Amplifier Design*", Prentice-Hall, Inc., 1987, pp. 96-101

[2] F. Giannini, R. Sorrention, J. Vrba, "*Planar Circuit Analysis of Microstrip Radial Stub*", IEEE Trans. on Microwave Theory and Tech., Vol. MTT-32, No. 12 Dec. 1984, pp. 1652 - 1654

[3] F. Giannini, M. Ruggieri, J. Vrba, "*Shunt-Connection Microstrip Radial Stubs*", IEEE Trans. on Microwave Theory and Tech., Vol. MTT-34, No. 3, March 1986, pp. 363 - 366.

5.0 CLAIMS

5.1 A Microwave stabilisation network comprising a transmission line of typically a quarter wavelength leading to a butterfly stub with a set of stabilisation resistors used to improve circuit stability or to ensure unconditional stability.

5.2 A stabilisation network as in Claim 1 but used in conjunction with high impedance lines and/or lump elements to provide a dc bias network as well as providing improved stability.

5.3 A stabilisation network as in Claim 1 or Claim 2 used in non-linear networks to provide improved stability over the operating dynamic range and environmental conditions.

5.4 As in Claim 1 or Claim 2 with dc de-coupling and rf coupling to provide stabilisation and/or biasing to dc or pulsed controlled switching networks.

5.5 As in Claim 1 or Claim 2 but used as a spurii suppression network.

Patents Act 1977
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Application number

GB 9305343.7

Relevant T chnical fields

(i) UK Cl (Edition L) H1W (WFA WFX WGA WGP)
H3W (WUV WVT)

(ii) Int Cl (Edition 5) H01P 5/02 H03F 1/08 1/56 3/19
3/191 3/193

Search Examiner

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Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI, INSPEC

Date of Search

8 JULY 1993

Documents considered relevant following a search in respect of claims 1

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	US 5177452 (HONJO) whole document	1-5

Category	Identity f document and relevant passages	Relevant to claim(s)

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